

A Theoretical Model for the Formation of Ring Moat Dome Structures: Products of Second Boiling in the Distal Parts of Lunar Basaltic Lava Flows. J. W. Head¹, L. Wilson^{1,2} and F. Zhang³ ¹Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02912, USA; ²Lancaster Environment Centre, Lancaster University, Lancaster LA1 4YQ, UK; ³Space Science Institute, Macau University of Science and Technology, Macau, China.

Ring Moat Dome Structures (RMDSs) are low mounds typically several hundred meters across surrounded by a moat. They occur relatively commonly in the lunar maria and appear to have formed synchronously with the surrounding mare basalt deposits. Originally recognized in images from the Apollo era, they have now been characterized in great detail using very high-resolution image and altimetry data from the Lunar Reconnaissance Orbiter. More than 2000 of these features have been documented in many of the maria. We have developed a theoretical model for the origin of these features that links them directly to our latest advances in understanding the volcanic processes emplacing the mare basalt lava flows. Lunar eruptions are typically driven by the penetration through the crust of large dikes that have travelled rapidly under buoyancy forces from their sources in mantle partial melt zones. Interaction with the crust decelerates the dikes until they reach a density-controlled equilibrium configuration, and this leads to predictable patterns in how the rate of eruption of magma and the style of the activity change with time. The initial volume flux is large and a hawaiian-style fire fountain forms over the vent from which pyroclasts accumulate to feed lava flows that have lost all of their volatiles to the lunar vacuum. These vesicle-free flows form the distal parts of the resulting lava flow field. Later phases of the eruption occur at progressively smaller volume fluxes and activity changes to strombolian explosions that punctuate a lava lake feeding late-stage lava flows having a distinctive morphology: a fragmental layer overlies a viscous vesicular layer, in turn overlying a low-viscosity vesicle-poor layer containing still-dissolved volatiles. The lowest of these layers can intrude the distal flows

late in the eruption as activity at the vent continues while the distal flows are coming to rest, a process seen in terrestrial flood-basalts. The intruded lava initially inflates the distal flows by a small amount. Subsequently, as the resulting compound flow cools progressively at its upper and lower surfaces, crystals form, and volatiles are concentrated in the remaining liquid. They soon reach saturation and gas bubbles then nucleate in increasing numbers in the areas where crystallization is greatest, forming magmatic foams. These foams can inflate the flow by a very considerable amount. Since the lava flows are generally emplaced on a cratered surface, they do not have uniform thicknesses, and differential inflation imposes flexural stresses on the cooled crust, causing cracks to form. Extrusion of the part of the foam with the lowest viscosity through the cracks and onto the surface of the flow is a viable way of forming the RMDS mounds. Subsidence of the lava flow surface to accommodate the load of the mound and preserve mass balance in the flow interior produces the moats surrounding the mounds. The model accounts for the amount of foam extruded and its physical state as it adjusts to the lunar surface environment and leads to predictions for the structure of the mounds that can be tested by future missions.